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(54) Voltage controlled integrated circuit for biasing an RF device.

(57) The present invention is directed to a voltage controlled single-package integrated circuit device, capable of thermal compensation, for biasing a quasi-linear bipolar device. The bias circuit also provides a low impedance source to a RF device so that the bias point does not dynamically change with the RF signal, thus improving linearity. Changes in the base-emitter voltage level of the RF device are monitored by a reference diode to provide automatic temperature compensation. The reference diode is in close thermal proximity to the RF device, allowing for accurate thermal tracking. The base-emitter voltage may be electronically adjusted by means of a control voltage input, such being suitable for hook-up to a computer system having a digital to analog convertor thereby allowing for fine voltage adjustments. The control voltage may also be used to adjust the class of operation of the RF device or provide external temperature control.

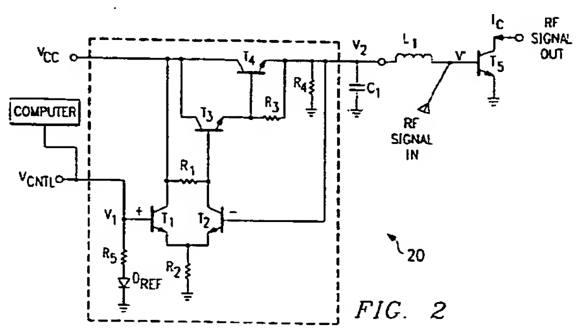

FIG. 2

EP 0 609 053 A2

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The present invention relates generally to an integrated circuit for biasing a quasi-linear bipolar device, and more specifically to a voltage controlled single-package integrated circuit device capable of thermal compensation for biasing such a device.

This application is related to European Patent Application No 93306576.5 the contents of which are incorporated herein by this cross reference.

It is well-known in the art that biasing circuitry is required for quasi-linear devices such as bipolar RF transistors. Quasi-linear devices are characterized as being in the common-emitter configuration with a conduction angle of 180 degrees to 360 degrees. The biasing circuitry must supply the proper current levels required by the device while compensating for drifts in the device operating point brought about by changes in ambient temperature and operating conditions. Systems which are not protected from temperature fluctuations are more susceptible to ambient temperature changes and system heat-sinking properties which are not optimal. If operating point drift is not addressed and remedied, catastrophic device failure, or "thermal runaway" may result.

Because of this potential danger caused by thermal variations, biasing circuitry has long monitored and compensated for fluctuations in temperature. Typically, the base-emitter voltage level of the RF device being biased is monitored and, when increases in temperature cause the voltage level to drop, the voltage is stabilized by decreasing the amount of current in the RF circuit. However, biasing circuitry of the prior art has usually included multiple active components, capacitors, and inductors, on a PCB. Since these components are usually fabricated by different suppliers, the RF characteristics of the active devices typically have different geometries and, thus, often do not exactly match the characteristics of the RF device being biased. In addition, the use of discrete components utilizes more valuable board space than would a biasing circuit on a single integrated circuit. This is very important in today's market of high performance, low cost, small RF power hybrid modules.

Besides thermal tracking of the biased device, another important concern is the ability to change class of operation as system demands dictate. Typical quasi-linear modes of operation include classes A, AB1, AB2, and B. It may be desirable to change a system's mode of operation to any one of these. For example, if more efficiency and less linearity of operation is required, it may make sense to change class of operation from class AB1 to AB2. The class of operation of an RF device is typically altered by varying the voltage supplied to the device. However, the prior art has not successfully addressed this need with a single-package integrated circuit device.

It is therefore an object of this invention to utilize biasing circuitry which monitors and compensates for changes in the operating point of a quasi-linear device caused by fluctuations in temperature or operating point.

It is further an object of this invention to utilize biasing circuitry capable of changing the class of operation of a quasi-linear device.

The present invention is directed to a voltage controlled single-package integrated circuit device, capable of thermal compensation, for biasing a quasi-linear bipolar device. The bias circuit also provides a low impedance source to a RF device so that the bias point does not dynamically change with the RF signal, thus improving linearity. Changes in the base-emitter voltage level of the RF device are monitored by a reference diode to provide automatic temperature compensation. The reference diode is in close thermal proximity to the RF device, allowing for accurate thermal tracking. The base-emitter voltage may be electronically adjusted by means of a control voltage input, such being suitable for hook-up to a computer system having a digital to analog convertor thereby allowing for fine voltage adjustments. The control voltage may also be used to adjust the class of operation of the RF device or provide external temperature control.

The novel features believed characteristic of the invention are set forth in the appended claims. The invention itself, however, as well as a preferred mode of use, and further objects and advantages thereof, will best be understood by reference to the following detailed description of an illustrative embodiment when read in conjunction with the accompanying drawings, wherein:

Figure 1 is a schematic of a biasing circuit for an RF device according to the prior art; and

Figure 2 is a schematic of a biasing circuit for an RF device according to the present invention.

Figure 1 shows a schematic of a biasing circuit 10 for an RF device according to the prior art. Comprised of discrete components, both passive and active, biasing circuit 10, as indicated by the dashed lines, is contained on a PCB and therefore does not reside in a single-package integrated circuit device. Reference diode D_{REF}, which is thermally coupled to the RF device, monitors the base-emitter voltage with respect to ambient temperature changes of the RF transistor being biased. An increase of 1 degree Celsius, yields a PN junction voltage decrease of 2 to 2.5 millivolts. As the ambient temperature increases, the PN junction voltage drops, causing the operating point of the device to drift. If this phenomenon is not stabilized, thermal runaway may be the result. When a base-emitter voltage drop is detected via temperature by reference diode D_{REF}, bias circuitry 10 compensates by supplying less voltage to the RF device. This compensation is accomplished by discrete components capacitor C_1, zener diode D_1, resistor R_3, comparator X_2, and reference diode D_{REF}. V_{CNTL} is a voltage input to bias circuit 10, whereby the voltage

supplied to the RF device may be controlled. OUT is the voltage signal to be fed to the base of the biased RF device.

Many different biasing circuits could be used to accomplish what is shown in **Figure 1**. However, it is important to recognize that this prior art is not a single package integrated circuit solution. Because the biasing circuit 10 is comprised of discrete components, both passive and active, board space is used and mismatch of RF characteristics between these discrete components and the RF device being biased is experienced.

Referring now to **Figure 2,** a schematic of a biasing circuit 20 for an RF device according to the present invention is shown. The components of biasing circuit 20, contained within the dashed lines, are contained in a single-package integrated circuit. Active components L_1 and C_1 provide RF decoupling to bias circuit 20. V_{cc}, the supply voltage, is a standard supply voltage similar to that used by many bipolar RF devices today.

D_{REF}, the reference diode, is placed in close thermal proximity to the RF device being tested - in this case, T_5 - and monitors the junction temperature of T_5 and thus the drift in the base-emitter voltage of T_5 with respect to ambient temperature changes. Since reference diode D_{REF} is thermally connected to biased device T_5, biasing circuit 20 will track T_5's base voltage in response to temperature changes in T_5, and maintain a constant quiescent collector current. Thus, class of operation and performance are maintained. For maximum thermal tracking, it is important that reference diode D_{REF} be placed in thermal proximity to biased device T_5. Since biasing circuit 20 is a single integrated circuit, close placement of D_{REF} to T_5 is facilitated.

As biased device T_5 heats up, reference diode D_{REF} senses this temperature change and bias circuit 20 adjusts the voltage value at voltage V_1 accordingly. A change in voltage V_1 is mirrored by a corresponding change in base-emitter voltage V' such that the collector current of the biased device I_c remains constant. It will be understood by those familiar with the art, that the value of resistor R_5 is relatively small and is chosen to establish V_{CNTL} at V_1 while allowing any decrease in the value of the PN junction voltage of T_5 to also be reflected at V_1.

The feedback loop which adjusts base-emitter voltage V_1 in response to changes in temperature is composed of differential pair T_1 and T_2 and Darlington pair T_3 and T_4. T_1 and T_2, with their emitters decoupled from ground via small resistor R_2, form a differential pair. It is advantageous for differential pair T_1 and T_2 to have closely matched characteristics so that they are balanced. When transistors T_1 and T_2 are made from the same die, as is the case here, matching is facilitated. Since V_2 is usually a constant value, R_2 represents a constant current source. Current which flows through R_2 is shared by T_1 and T_2. If V_{CNTL} is increased, T_1 turns on more, thereby providing less current to T_2 and more current for Darlington Pair T_3 and T_4, causing V_2 to increase.

Darlington pair T_3 and T_4 provide bias circuit 20 with a low impedance current source as required by ideal voltage source V', and therefore serves to pass through current needed to maintain emitter-base voltage V' at a stable level independent of the current needs of biased device T_5. Darlington pair T_3 and T_4 are especially attractive because of the extra current gain they offer. They provide increased sensitivity for a more stable output voltage and a lower output impedance than would otherwise be achieved. Resistor R_4 is used to provide a current sink option for bleeding excess charge; in this way, bias circuit 20 can both source and sink current thereby eliminating the need to rely on T_5 to sink current.

The physical size of Darlington transistors T_3 and T_4 can be increased so that they are capable of passing more current. If this increase in size is implemented, differential pair T_1 and T_2 may also need to be larger in order to withstand the larger current which will flow through R_1. And, while T_3 and T_4 offer excellent current gain characteristics, they could be replaced by other circuitry, such as a single-pass transistor, if less current gain is acceptable.

The presence of transistor T_1 allows emitter-base voltage V' to be electronically controlled. Control voltage input V_{CNTL} provides the means by which the user may adjust V' as required. Changing V_{CNTL} also allows the class of operation of the biased device to be changed. For instance, hooking up control voltage input V_{CNTL} to a computer which possesses a digital to analog convertor would allow frequent and minute adjustments to be made to V_{CNTL}, thereby changing the voltage at the base of T_1 and, in turn, the value of base-emitter voltage V'.

As described above, when base-emitter voltage V' is changed, the collector current I_c of biased device T_5 also changes, allowing its class of operation to be changed. Biased device T_5 may be operating in the Class AB1 mode if a linear range of operation is desired. Changing the value of V_{CNTL} can push biased device T_5 into a Class AB2 mode of operation which may be desirable if greater efficiency and a smaller linear range of operation is required. Changing the class of operation of biased device T_5 is accomplished by simply varying the voltage level of V_{CNTL} and does not require changing any components in biasing circuit 20. This advantage differentiates the invention over the prior art.

An improved structure for biasing devices has been described. Any bipolar device operating in the quasi-linear mode where thermal runaway is an issue and where it might be advantageous to change the class of operation during operation stands to benefit from the invention described herein.

While the invention has been particularly shown and described with reference to a preferred embodiment, it will be understood by those skilled in the art that various changes in form and detail may be made therein without departing from the spirit and scope of the invention. For instance, reference diode D_{REF} is described as the means by which the junction temperature of biased device T5 is monitored. However, one skilled in the art will understand that other semiconductor temperature sensing devices, such as a transistor, may be used. Additionally, an active current source, rather than resistor R_2, could be used to decouple the emitters of differential pair T_1 and T_2 to ground.

Claims

1. A single package integrated circuit device for biasing a quasi-linear bipolar device, comprising:
   a differential transistor pair, having a first transistor and a second transistor wherein the emitters of the first and second transistor are connected;
   a Darlington transistor pair, having a third and a fourth transistor, with the base of the third transistor connected to the collector of the second transistor and the base of the fourth transistor connected to the emitter of the third transistor;
   a reference device for monitoring the base-emitter voltage of the biased device;
   a voltage control input, for electronically adjusting the base-emitter voltage level of the biased device, connected to the base of the first transistor; and
   means for changing the class of operation of the biased device.

2. The biasing device of claim 1, wherein changing the class of operation of the biased device is accomplished by changing the voltage level of the voltage control input.

3. The biasing device of claim 2, wherein the voltage control input is suitable for control by a computer such that frequent and small changes in voltages may be realized.

4. The biasing device of claim 2, wherein class of operation refers to classes A, AB1, AB2, and B.

5. The biasing device of claim 1, wherein the reference device is in close thermal proximity to the biased device.

6. The biasing device of claim 5, wherein the reference device is a diode.

7. The biasing device of claim 1, wherein the emitters of the first transistor and the second transistor are decoupled from ground through a small resistance.

8. The biasing device of claim 7, wherein the small resistance is a resistor which behaves as a constant current source and the current through the resistor is shared between the first transistor and the second transistor.

9. The biasing device of claim 1, wherein the collector of the third transistor and the collector of the fourth transistor are connected to the power supply.

10. The biasing device of claim 1, wherein a resistive element supplies current from a power supply to the base of the third transistor.

11. The biasing device of claim 10, wherein the resistive element is a resistor.

12. The biasing device of claim 1, wherein the biased device is a bipolar RF transistor.

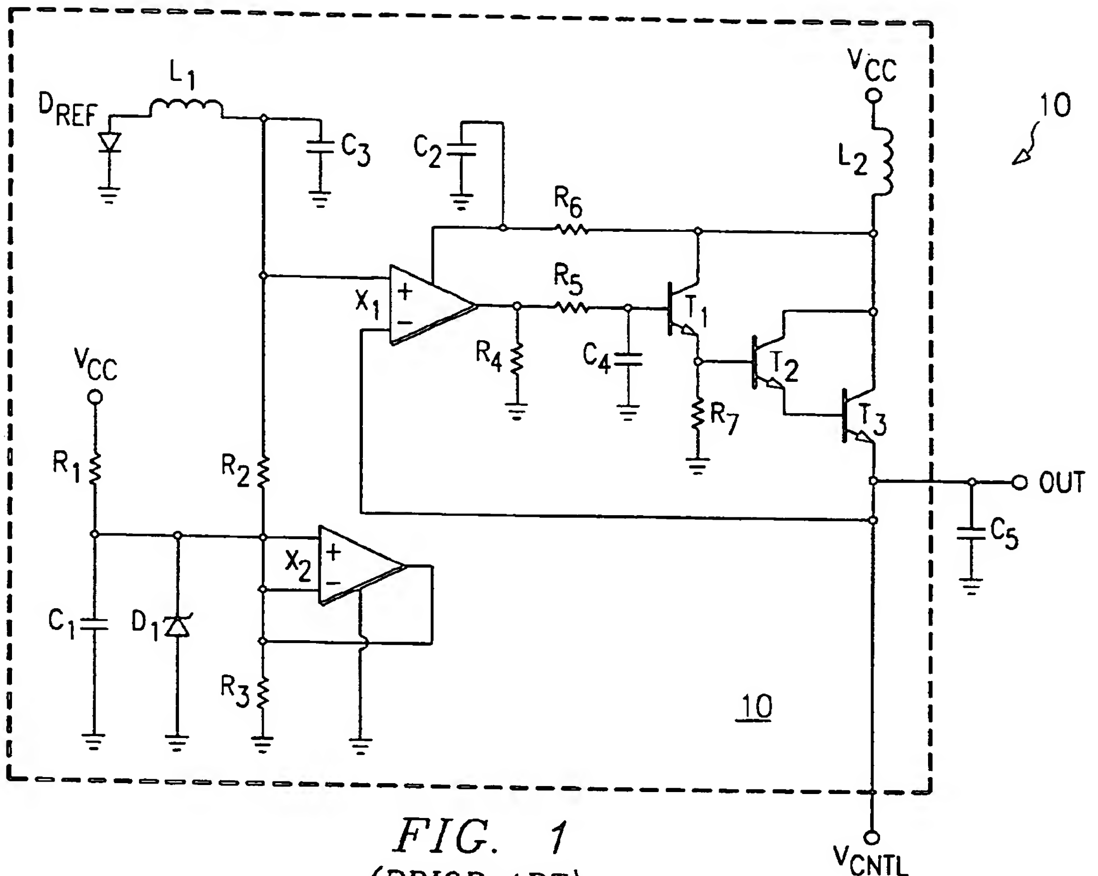

FIG. 1
(PRIOR ART)

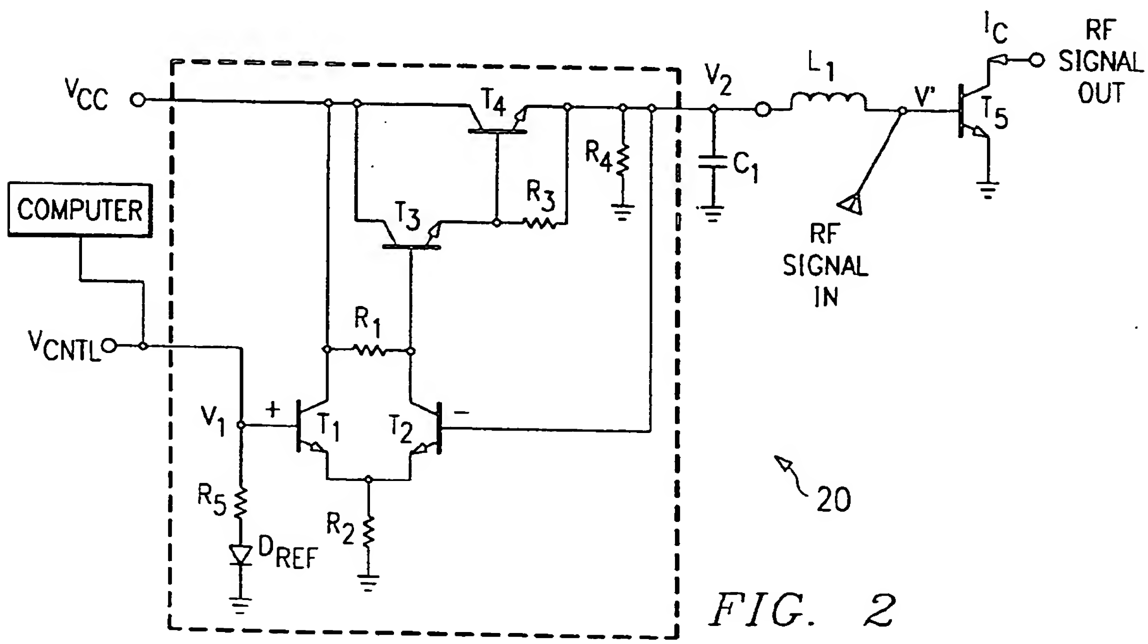

FIG. 2